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Effects of NPK and plant tea manure (*Tithonia diversifolia*) on growth rate of amaranth (*Amaranthus cruentus* L.) in soilless growing media

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Many countries are running short of agricultural land. Even where land appears to be available, soil fertility, water availability as well as nutrient mining still remains a challenge yet at the same time the world's demand for food is rapidly increasing. Millions of square meters of soil are mined each year for use in vegetable nurseries and in backyard gardens in addition to excessive use of inorganic fertilizers. There are however a number of soilless growth media and organic sources of plant nutrients that could be used to address this problem. This study investigated the effects of application of NPK (Nitrogen, Phosphorus and Potassium) and plant tea (*Tithonia diversifolia*) manure on selected soilless growing media on growth rate of *Amaranthus cruentus* L. This was to determine their suitability as an alternative growing media. A split plot design was used and the experiments carried out for two seasons. The soilless growing media investigated were: charcoal dust, saw dust, dry coffee husks, and mixture of charcoal and saw dust (1:1), saw dust and coffee husks (1:1), charcoal dust and coffee husks (4:1) and a compound mixture of charcoal dust, sawdust and coffee husks (2:2:1). The growing media were randomized in the three split blocks with eight pots each. Growth rates in terms of shoot height, number of leaves, leaf length, leaf width, stem girth and root length were measured for two seasons. Results indicated that all the growth media could support amaranth growth. However, a mixture of charcoal dust and dry coffee husk (4:1 respectively) with application of plant tea manure significantly affected the growth rate of *A. cruentus* ($p<0.05$). Mixture of charcoal dust and dry coffee husk (4:1 respectively) with application of either NPK or plant tea manure could be used as the best alternative growth media. Soilless growth media that constituted of charcoal dust and coffee husks could be explored for amaranth production in home kitchen gardens in rural areas and backyard gardens in urban areas.

Key words: Soil, soilless growing media, plant nutrients, amaranth.

INTRODUCTION

According to Wilkinson et al. (2014), surveys of tropical and sub-tropical areas of Africa, Asia, and Latin America showed unexpectedly poor field growth of seedlings after out planting, and correlated this problem with poor root development because of using soil-based media in nurseries. These nurseries could be for vegetables, fruits and trees. One of the major challenges soil-based agriculture poses is its vulnerability to pests and diseases, environmental changes such as floods, wind, drought and climate change. These changes can lead to huge losses for farmers (Bout Well, 2014).

Butler and Oebker (2006) reported that soil-based agriculture is facing some major challenges, with the advent of civilization all over the world, such as decrease per capita land availability, incidence of pests and diseases, soil degradation among others. The degraded soils require constant addition of inorganic fertilizers if any better plant growth is to be achieved. These inorganic fertilizers are relatively expensive and most local rural people may not afford them. Apart from this, due to rapid urbanization and industrialization as well as threats from climate change and its related adverse effect, the land cultivation is going to further face challenging threats (Mgbemene et al., 2016).

Over the years, vegetables have been grown on natural soil, however with the increase in population especially in urban centers, growing vegetables like *Amaranthus cruentus* is carried out in containers, sacks within the compounds and backyard gardens with natural soil as a growth media. According to Husain et al. (2014) the soil used is normally collected (mined) from other places like from the forest, swamp and gardens. This has led to soil nutrient mining which is one the greatest threats to agricultural production, decreased crop yields and per capita food production, in the mid to long term, a key source of land degradation and environmental damage according to Henao and Baanante (2006).

Besides, poor soil fertility in some of the cultivable areas, less chance of natural soil fertility build-up by microbes due to continuous cultivation, frequent drought conditions and unpredictability of climate and weather patterns, rise in temperature, river pollution, poor water management and wastage of huge amount of water, decline in ground water level, etc., are threatening food production under conventional soil-based agriculture. Under such circumstances, in near future it will become impossible to feed the entire population using open field system of agricultural production only. Naturally, soil-less culture is becoming more relevant in the present scenario, to cope-up with these challenges. In soil-less culture, plants are raised without soil. Improved space and water conserving methods of food production under soil-less culture have shown some promising results all over the World (Sengupta and Banerjee, 2012).

The recommended alternative according to Soga (2010) is to replace soil-based media whenever possible with organic-based media. If soil must be used, it should be only a small percentage of the mix, amended with other ingredients to overcome some of the problems. According to Nkonya et al. (2012) about 60% of the total land area is marginally suitable for cultivation due to limited organic matter and water retention capacity while close to 30% is considered degraded and vulnerable to erosion. Sub-Saharan Africa suffers from extensive soil degradation, threatening the livelihoods of the 70% of Africans who are involved in agriculture. The poor quality of soils is another constraining environmental factor. For example, phosphorus deficiency, low organic content, and low water infiltration and retention capacity on much of African soil have been limiting factors in agriculture. Unlike climate variability, this problem can be addressed: soil quality can be augmented through careful management and soil nutrient supplementation.

Depardieu et al. (2016) reported that due to increasing risks of water scarcity resulting from climate change and the intensification of crop production worldwide, the agricultural sector needs to improve water use efficiency for crop production. At present, soilless cultivation under protective conditions is an intense cultivation method that can provide more efficient use of water. The increasing demand for low cost, environmental friendly and highly performing soilless substrates for crop production has led to the search for alternative materials as constituents of growth media such as organic wastes from the agri-food and agriculture industries. Organic substrates are usually preferred because of their low costs, biodegradability and their high productivity potentials (Caron et al., 2015).

Soilless growing media

The origins of soilless culture go back at least to the 17th century when, in 1666, Boyle attempted to grow plants in "vials containing nothing but water", and reported that one species (spearmint, *Raphanza aquatica*) survived for nine months (Olympios, 1999). Soilless cultivation addresses the problem of dwindling farmlands, as plant roots do not need to stretch much to reach nutrients; the nutrients they need are supplied in the nutrient formula (Bout Well, 2014).

According to Olympios (1999), the main advantages of soilless culture are the most accurate control over the supply of water, nutrients, pH, root temperature, increase productivity due to easier and more accurate control of production factors, reduction of labour requirement, no need for soil sterilization and more crops per year. With soilless agriculture, plants may be cultivated indoors, where they are protected against potential destructive environmental elements. Crop yields are also stable and much higher due to the use of artificial lighting, making it possible to grow year-round. Soilless cultivation requires little-to-no pesticides or herbicides, or can get by using minimal amounts of organic options. Crops grown in protected environments are fed optimally and experience less stress. This makes them better able to resist the pests. Furthermore, weeds are not a problem in soilless

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cultivation since they require soil to grow (Boutwell, 2014).

According to Bhardwaj (2013) and Salisa et al. (2016) in studies on effects of soilless growing media on germination of different plants, found out that growing media plays important role in seedling emergence and quality of the seedlings produced. A good growing media provides sufficient anchorage or support to the plant, reservoir for nutrients and water and permit gaseous exchange between root and atmosphere outside the root substrate (Sardoei and Shahdadneghad, 2015).

Coffee husks

According to Nguyen et al. (2013) coffee husks may be added into soil when used alone or in combination with NPK. Application of fertilizers as amendments improves the chemical characteristics of the soil. The reduction in mineral fertilizer application through their supplementation with organic sources, such as coffee husk makes the use of soil nutrient amendments affordable to small holder farmers, guarantees and improves soil life. Application of coffee waste in sandy soil increases the availability of phosphorus, retained soil water from 53 to 60%. It also promotes the retention of basic cations and immobilized manganese. Coffee waste also has the potential to be used as a liming material, NPK fertilizer and has the benefit of increasing water and nutrient retention (Kasongo et al., 2011).

Charcoal dust

Ukrfuel (2015) reported that moisture content together with the ash content are very important charcoal's chemical properties that define its quality. Moisture lowers the heating value of charcoal. Usually fresh charcoal from the kiln contains less than 1% of moisture, however due to humidity of the air the moisture content can reach 5 to 10%. When the hygroscopicity of charcoal increased, the moisture content of charcoal can rise to 15% or even more. The reason for high cation exchange capacity on charcoal dust is due the process of pyrolysis that causes increase in the surface area after pyrolysis. Secondly, there is an increase in charge density on the surface. Generally, the higher the pyrolysis temperature the higher the charcoal dust surface area. This high surface area is in the form of micro/nanopores (Gomez-Eyles et al., 2013).

Saw dust

According to Tran (2005), sawdust holds potential as a contributing carbon source for increasing soil organic matter when applied to soil. Marinou et al. (2013) also added that sawdust is widely used as a growth medium component in areas with wood processing industries, because of its low cost, high moisture retention, and high availability.

Plant nutrients (NPK)

According to Mariana et al. (2015), soil is the main source of mineral nutrients and water for plants, but its ability to provide plant nutrients needed varies depending on the level of fertility. The removal of nutrients from the soil into the plant by sucking them through leaching or other processes related to the natural dynamics of soil, reducing entail the contents of mobile forms of nutrients and the gradual decline of production capacity of soils. For these reasons, it is necessary to applying mineral and organic fertilizers. Plants require essential nutrients for normal functioning and growth. A plant's sufficiency range is the range of nutrient amount necessary to meet the plant's nutritional needs and maximize growth (McCauley et al., 2011).

NPK fertilizer is primarily composed of three main elements: Nitrogen (N), Phosphorus (P), and Potassium (K), each of these being essential in plant nutrition. Among other benefits, Nitrogen helps plants grow quickly, while also increasing the production of seed and fruit, and bettering the quality of leaf and forage crops. Nitrogen is also a component of chlorophyll, the substance that gives plants their green color, and also aids in photosynthesis (Okese, 2016).

Plant tea manure made from Tithonia (*Tithonia diversifolia)*

Tithonia produces a nutrient-rich (N, K and P) biomass and its positive effect on subsequent rice and maize crops has been reported from Africa and Brazil as reported by Partey (2010). In addition, *T. diversifolia* causes immediate and sustained increase in soil pH and an immediate and sustained decrease in extractable Aluminium in soils. Its abundance and adaptability, coupled with its rapid growth rate and very high vegetative matter turnover, makes it a candidate species for soil rejuvenation and improvement, as a green manure or as a major component of compost manure. Different practices have been reported: Mexican sunflower can be left to decompose on the field, or it can be turned into green manure according to Olabode et al. (2007).

Amaranth (*A. cruentus*)

Common names: purple amaranth, red amaranth, red shank, bush greens, African spinach, Indian spinach (En.); amaranteétalée, queue de renard (Fr.); achita, bledo (Sp.). This amaranth species was domesticated as a grain in Mesoamerica and found its way to the tropics and subtropics of the Old World during colonial times. It is used for grain production (pseudo cereal), as a leafy vegetable, and for ornamental purposes. In tropical Africa it is a traditional, highly productive, nutritious and economically important leafy vegetable (Andreas, 2011). Amaranthus originated in America and is one of the oldest food crops in the world, with evidence of its cultivation reaching back as far as 6700 BC.

Most of the vegetables consumed in the urban centres in sub-Saharan Africa are grown on soil mined and collected far away from swamps, forest or gardens. The yield from these soils does not match with high demand of vegetables therefore more has to be transported from some miles away in the rural villages using motor cycles and vehicles. This leads to soil nutrient mining which is one the greatest threats to agricultural production, decreased crop yields and per capita food production. This is one of the mid to long term, a key source of land degradation and environmental damage according to Henao et al. (2006). Transporting of vegetables using motorcycles and vehicles which use the fossil fuels contributes to the carbon dioxide emissions that are responsible for the greenhouse gases and their effect on global warming and climate change. According Viljoen and Bohn (2014) when food is produced in the city, food miles are generally reduced which may as well reduce carbon dioxide emissions linked to it (Viljoen and Bohn, 2014).

Many countries are running short on agricultural land at the same time the world's demand for food is rapidly increasing. Soil and water fertility decline, nutrient mining still remain a challenge in many countries in sub-Saharan Africa. Harvesting topsoil is actually a mining operation that uses up a limited resource that took thousands of years to develop. Millions of square meters of soil are mined each year for use in, vegetable nurseries and in backyard gardens in addition to excessive use of inorganic fertilizers. However, soil fertility status has attained a saturation level, and productivity is not increasing further with increased level of fertilizer application (Sengupta and Banerjee, 2012). There are however a number of soilless growth media and organic source of plant nutrients that could be used to address this problems.

METHODOLOGY

This study was conducted in Luweero District in Central Uganda, 0.712°N, 32.1250 specifically at Bukalasa Agricultural College green house. The green house was typical standard green house for horticultural production in tropical Africa. It was well insulated with a transparent and translucent polyethene material. The inside environment was well aerated with temperature ranging from 24°C in a cool weather to 30°C on warm weather conditions. The source of water was from the taps and watering using Watering Can. This was regularly carried out early in the morning and sometimes in the evening depending on the weather conditions (Jyopti and Davidson, 2015).

Preparation of research materials

To determine the effects of application of NPK, plant tea manure on selected soilless growing media on plant growth, an experiment was conducted using *A. cruentus* L. as model plant. The different growing media were prepared by carrying out the following activities: sorting, sifting and boiling. The dry coffee husks (Robusta coffee husks) were boiled in order to soften it. The different media were measured in the right ratios, mixed and potted. Proper mixing of the media was ensured to avoid variations in container plant quality. The pots were arranged in randomized blocks in the greenhouse and watered thoroughly (Brein, 2013).

The sources of plant nutrients included NPK (17:17:17) which was purchased from the farm shops. It was applied at a rate of 2 g/pot. Tithonia (*Mexican sunflower*) was obtained from the college farm hedge. Plant tea manure was prepared from fresh Tithonia (*Mexican sunflower)* leaves (1 kg) cut into small pieces of 3 to 4 cm and soaked in 10 L of water, kept in the dark place and stirred regularly for 7 days (Nalunga, 2014; Partey, 2010). After that it was filtered to remove the residues and the filtrate is diluted at a ratio of 1 L:10 L of water for root application or 1 L:20 L for foliar application of plant tea manure and water, respectively. Each of the different sources of nutrients was applied to specific plots as shown in the research design (Koller et al., 2016).

The experimental design

A split plot design was used to carry out the investigations. Using this design enabled the control of all other factors which would have affected the research experiment. It also helped in making comparisons between the effects of different sources of nutrient (treatments) on soil and the different soilless growing media on growth rate of *A. cruentus* (O'Connor et al., 2018).

Twenty four 10 L plastic experimental pots, each perforated at the base to permit drainage of excess water each were filled with: soil, coffee husks, sawdust, and the different combinations of the soilless growth media, respectively as shown in Table 1. The distance between blocks was 1 m apart and between pots in the respective blocks was 30 cm and were randomly arranged (Koller et al., 2016; Brein, 2013).

All the pots were watered and left to rest for 48 h. *A. cruentus* seeds mixed with sand were planted in each pot with a spacing of 2 cm×10 cm and covered thinly with soil. At the growth period of 2 weeks, the plants were thinned and six plants were left to grow in each of the pots throughout the experimental period (Kamara et al., 2016).

The first group (block 1) of plants in the different growth media (T1 - T8) received no treatment and was used as a control. The second group (block 2) received NPK (17:17:17). The third group (block 3) received plant tea manure on weekly intervals (Tithonia plant tea manure). The two treatments were applied at 2 weeks after planting. The plants were allowed to grow and watered at alternate days as necessary. Subsequently, the growth parameters were recorded on weekly intervals for 5 weeks. By this time most of the plants in the different growing media and the different combinations with the different sources of nutrients had reached reasonable size for better observations and recording of data (Both et al., 2015).

Data collection methods and tools

The methods use to collect date included physical observation and measurements. The tools included camera (photographs), 30 cm ruler, and 3 m tape measure to measure leaf length, width and shoot height. Vernier calipers (12.5 cm Chinese make) were used to measure the stem girth. The shoot height was measured from the

Table 1. (a) Showing growth media composition of different plant growth media used in the research. (b) Layout of the experiment

Growth media	Growth media (% or volume ratio)
T1	Natural soil 100%
T2	Saw dust 100%
T3	Charcoal dust 100%
T4	Coffee husks 100%
T5	Saw dust + charcoal dust (1:1)
T6	Saw dust + Coffee husks (1:1)
T7	Charcoal dust + Coffee husk (4:1)
T8	Charcoal dust + Saw dust + coffee husks (2:2:1)

Control (Block 1)	NPK (Block 2)	Plant tea (Block 3)
T1	T4	T6
T2	T8	T5
T3	T7	T1
T4	T6	T3
T5	T2	T7
T6	T3	T8
T7	T1	T4
T8	T5	T2

collar region to the end of the shoot tip or foliage. The stem girth was measured at the collar region (cotyledon scar) using the vernier calipers. The root length was measured from the collar region to the end of the tap root tip (Pooter et al., 2016). The seed emergence was verified by observing the seedlings that had emerged in each pot in the first four to five days (Carta et al., 2016).

At 2 weeks after planting, the initial growth and development parameters such as number of leaves and shoot height were recorded. Thereafter as the seedlings growth progressed observations on growth indicators were recorded on weekly basis. *A. cruentus* has soft and tender stems that are quite delicate therefore the stem girth and the root length were determined at the end of the experiment. After termination of the first experiment the different growth media were left to rest for one month then fresh seeds were planted. This was used to determine whether the different soilless growing media can be reused for growing (Barrett et al., 2016).

The data recorded were analyzed using SPSS Version 16 and Genstat 2.0 software packages. For each response variable, two phases of statistical analysis were employed. The first step involved one way analysis of variance (ANOVA) to compare whether the observed response among the main factors of interest; different growing media and treatments were significant. The second phase involved further analysis in comparing means to detect the differences among the different growing media and the treatments. The means of significant response parameters were separated using the Tukey-Kramer Honestly Significant Difference (HSD) test at $p<0.05$ level of significance. This was used for separating means of different plant growth parameters and their level of significance and to determine the differences between groups (Abdi and Williams, 2017).

FINDINGS

Shoot height

Figure 2 shows clearly that the soilless growing media that had the best performance in terms of shoot height is T7 (mixture of charcoal dust and coffee husks 4:1, T3 (charcoal dust) and T4 (coffee husks). However, T7 had the highest coefficient of variation compared to all the other soilless growing media. Further analysis was conducted using ANOVA in Table 3.

There was a significant difference between means of heights of *A. cruentus* grown in different growing media at $p<0.001<0.05$. These findings confirm the observations illustrated in Figure 1. It indicated that the application of NPK and plant tea manure affects the growth rate of *A. cruentus*, shoot height in particular. From these findings therefore the null hypothesis which stated that application of NPK and plant tea manure on selected soilless media has no effect on the growth rate of *A. cruentus* was rejected.

The data on Tables 3 and 4 present sufficient evidence that there was a statistically significant difference in shoot height in different growing media and treatments. These clearly show that the different growing media and treatments have effects on the growth in height of *A. cruentus.*

Number of leaves

The data in Table 5 shows that there was statistically significant evidence that different treatments have an effect in growth in the number of leaves ($p<0.001<0.05$).

Stem girth

The data in Table 7 shows that there was statistically

Figure 1. Making observations and recording data.

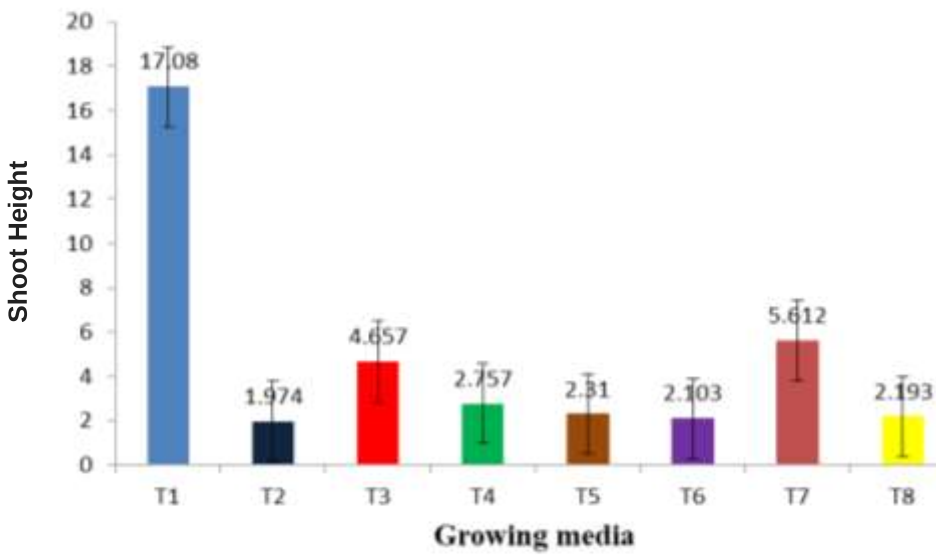

Figure 2. Shoot height in different growing media.

Table 3. Summary of ANOVA on shoot height in different growing media.

Shoot height	Sum of squares	df	Mean square	F	Sig.
Between Groups	25367.692	7	3623.956	143.662	0.001
Within Groups	28857.982	1144	25.226	-	-
Total	54225.675	1151	-	-	-

significant evidence that the stem girth of *A. cruentus* was different in the different growing media. This further confirms that application of NPK and plant tea manure has an effect on the growth rate (attributes) of *A. cruentus.* The null hypothesis which states that application of NPK and plant tea manure on soil soilless

Table 4. Summary of ANOVA on shoot height of in different treatments.

Shoot height	Sum of squares	df	Mean square	F	Sig.
Between Groups	487.295	2	243.647	5.210	0.006
Within Groups	53738.380	1149	46.770	-	-
Total	54225.675	1151	-	-	-

Table 5. Summary of ANOVA on number of leaves of in different treatments.

No. leaves	Sum of squares	df	Mean square	F	Sig.
Between Groups	1525.352	2	1525.352	67.478	0.001
Within Groups	19485.741	862	22.605	-	-
Total	21011.093	863	-	-	-

Table 6. Summary statistics for stem girth in different growing media.

Growth media	T1	T2	T3	T4	T5	T6	T7	T8
Mean	0.794	0.0233	0.35	0.058	0.0654	0.0322	0.48	0.0383

Table 7. Summary of ANOVA stem girth in different growth media.

Stem girth	Sum of squares	df	Mean square	F	Sig.
Between Groups	20.322	7	2.903	106.409	0.001
Within Groups	7.639	280	0.027	-	-
Total	27.961	287	-	-	-

Table 8. Summary of ANOVA root length in different growing media and treatments.

Parameter		Sum of squares	df	Mean square	F	Sig.
	Between Groups	7710.841	7	1101.549	120.905	0.001
Root length	Within Groups	2551.034	280	9.111	-	-
	Total	10261.875	287	-	-	-
	Between Groups	0.000	7	0.000	0.000	1.000
Treatment	Within Groups	192.000	280	0.686	-	-
	Total	192.000	287	-	-	-

growth media has no effect was therefore rejected.

Root length

Data in Table 8 clearly shows that there was a statistically significant difference in root length between groups in different soilless growing media ($p<.001<0.05$) (Figure 3). However, the data also showed that root length was not statistically significant in different growth media with the application of the different treatments ($p>1.00>0.05$).

DISCUSSION

The results indicate that the application of NPK and plant tea manure has effect on the growth of *A. cruentus* on

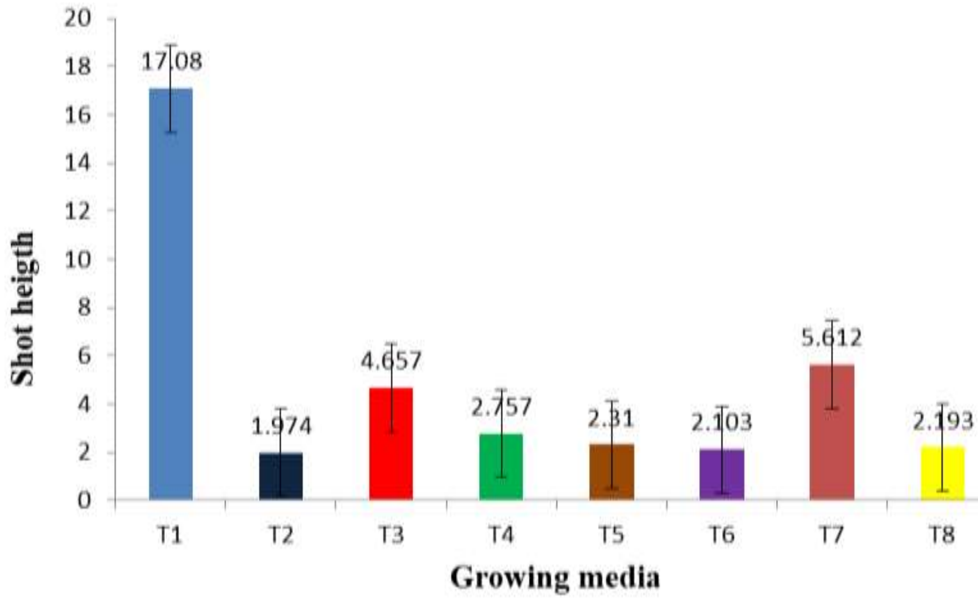

Figure 2. Shoot height in different growing media.

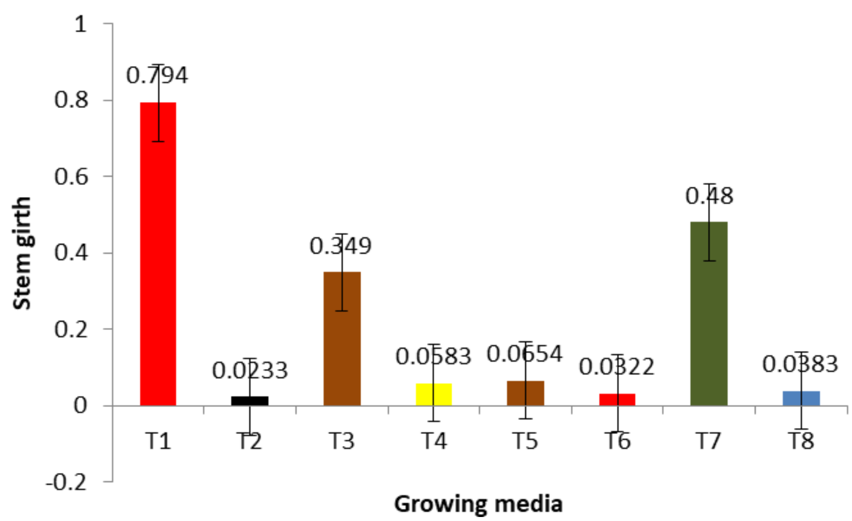

Figure 3. Stem girth in different growing media.

selected soilless growing media (Makinde et al., 2011).

Shoot height

Figures 2 and 3 reveal that the soilless media T7 had better performance compared to the rest. The mixture of coffee husks and charcoal dust had a significant effect on the shoot height of amaranth. This is in line with Rabani (2018), he found that growth media affects roots as well as shoot growth of lentils. Similar findings were also reported by Crush et al. (2005) and Olosunde et al. (2009).

Number of leaves and stem girth

As shown on Tables 5 and 6, the leaves and shoot height were similarly affected by the growth media as well as the stem girth. These findings confirm that of Chalwa and Mahta (2015) who also found that growing media affects the survival and growth of transplanted Litchi layers with better root development and therefore better leaf growth. Ibironke and Victor (2016) also reported similar results

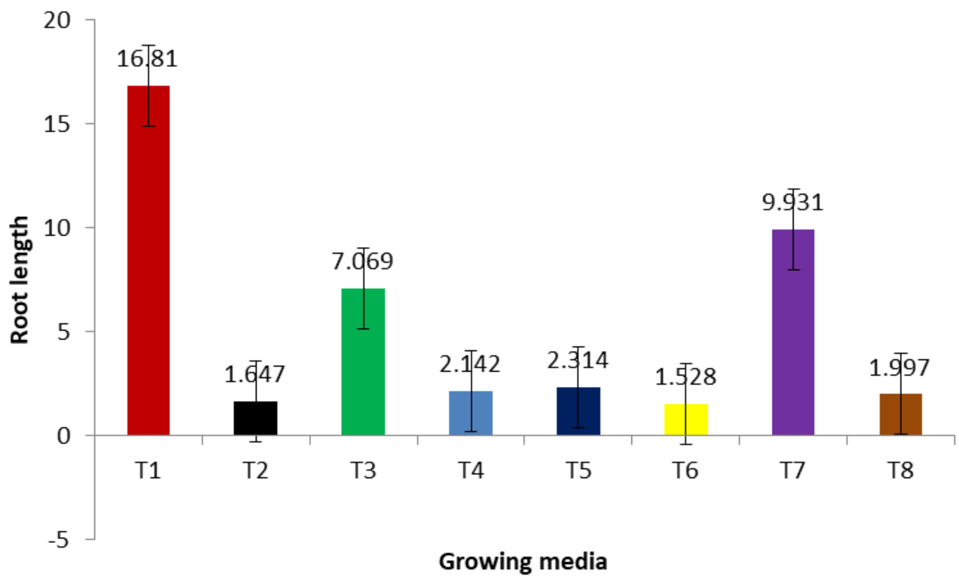

Figure 4. Root length in different growing media.

that growth media has significant influence on number of leaves per plant. However other soilless growing media showed no significance on the number of leaves and the stem girth. This could be attributed to their structural differences and ability to release nutrients required for plant growth (Olubanjo and Alade, 2018).

Root length

T7 still showed the significant effects on the root length of amaranth. These findings are also in line with the study carried out by Magesa et al. (2017) where he found that growth media affects the rooting stem cuttings of hybrid coffee. These results show that root length is determined by the media where it is grown. Furthermore Fagge and Manga (2011) found that root length in most cases is related to the growing media. Growing media that has good structure with enough pore space and ability to hold adequate water and plant nutrients for plant growth is an ideal media for proper root growth (University of Maine, 2019).

The mixture of coffee husks and charcoal dust is well aerated, porous thereby promoting rapid absorption of nutrients facilitating root penetration and eventual plant growth observed in shoot height, number of leaves, stem girth, and root length among others. Therefore, addition of either NPK or plant tea manure further enriches the mixture with plant nutrients. Fairhurst (2012) reported that coffee husks when added into the soil improve its chemical properties. These chemical properties include water holding capacity, aeration and cation exchange capacity (Mukherjee, 2013; Gomez-Eyles et al., 2013). Growing media with a high cation exchange capacity withhold cation and act as a long-term cache. In general, an abundance of small to medium-sized pores can enhance the surface area of the material. The high surface area of charcoal dust provides space for formation of bonds and complexes with cations and anions with metals and elements on its surface which improves the nutrient retention capacity. This high surface area is in the form of micro/nanopores that can tightly trap ions (e.g., NH_4^+) and water cannot flush them out (Haven, 2010). This capacity is the reason charcoal dust is able to hold water for long compared to other soilless growth media (Barrett et al., 2016).

Coffee husks are organic substrates which are highly biodegradable. Therefore, after it breaks down it avails all the nutrients for pant growth. This confirms the report by Caron et al. (2015). Kasongo et al. (2011) also reported that addition of coffee husks in soil promote the retention of basic cations and immobilized manganese as improving the pH of soil due its liming properties.

Charcoal dust is porous and hygroscopic in nature which makes it absorb moisture from the air. The porous nature also makes it well aerated therefore facilitating root penetration and eventual plant growth. These properties also make charcoal dust to hold water, regulate its temperature due to its dark colour and availability of nutrients for plant growth. This confirms the report by Ukrfuel (2015) that quality charcoal has the moisture content of around 5 to 15% of the gross weight of charcoal.

Conclusion

The findings of the study showed that NPK and plant tea manure influence significantly the growth rate of *A. cruentus* grown on a mixture of charcoal dust and coffee husks as a growing media. *A. cruentus* reached a height of 26 cm at 5 weeks from the time of planting. This growth rate is even higher than for natural soil conditions. Therefore, the best alternative soilless growing media that gave outstanding performance on the growth attributes of *A. cruentus* was the mixture of charcoal dust and coffee husks in the ratio of 4:1, respectively. It can therefore be used as an alternative growing media for growing *A. cruentus* and plant tea manure as an alternative source of plant nutrients.

RECOMMENDATIONS

Rising tree and vegetable seedlings in nurseries as well as kitchen gardening and urban farming should be carried out using the soilless growing media: a mixture of charcoal dust and coffee husks. Harvesting topsoil is not a sustainable operation that uses up a limited resource that took thousands of years to develop. Therefore, by using the soilless, soil mining, nutrient mining, food miles, soil degradation and environmental pollution could be avoided. Coffee husks as a bio-waste should be put to agricultural use by mixing it with charcoal dust so that it is properly put into useful use. This will also further help to reduce soil degradation and environmental pollution which are of great challenge in soil based agriculture and also proper management and disposal of coffee husks which present major challenges in countries where coffee is produced in large scale.

More research is needed on the different soilless growing media in open field conditions so that the findings could easily be adopted by the people even in local communities who do not have green houses. Furthermore, there is need to carry out research to determine the nutritive profile of *A. cruentus* grown on soilless growing media. Carrying out this would help in establishing the possibility of coming up with a soilless media with best quality growth conditions and *A. cruentus* with higher nutrients (higher quality) which is good for human health. This would further help the current vitamin A deficiency which is one of the major health problems in Uganda and sub-Saharan Africa at large.

Further research should also be carried out to determine the possibility of using charcoal dust as a growing media for other vegetables like tomatoes, egg plants and other African leafy vegetables that are highly nutritious as well as in flower farms to avoid the importation of cocoa peat which is expensive.

There is need to establish the possibility of popularizing amaranth as a leafy and grain vegetable as an alternative vegetable/crop which requires less inputs, easy to establish and manage for income generation in marginal areas in Uganda

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CONFLICT OF INTERESTS

The authors declare that they have no conflict of interest.

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